Chipping of veneering ceramic on a lithium disilicate anterior single crown: Description of repair method and a fractographic failure analysis

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Abstract: OBJECTIVE This article presents a retrospective analysis of an anterior single crown that showed chipping of the veneering ceramic, the clinical stages of intraoral repair made in composite resin, and fractographic analysis of the causes of failure. CLINICAL CONSIDERATIONS The ceramic chipping occurred in the incisal and labial surfaces of the crown, 1 year after installation. Clinical examination revealed the presence of occlusal interference, which was probably responsible for chipping. Vinyl-polysiloxane impression was made from the patient, and epoxy replica was produced. The replica was gold coated and inspected under the optical microscopy and scanning electron microscope (SEM) for descriptive fractography. Optical microscopy and SEM images showed that chipping initiated at the incisal edge, where it is possible to note an area of damage accumulation. At the labial surface, multiple arrest lines with their convex sides facing the incisal edge were observed. The fractured area was repaired intraorally with composite resin, and the patient's occlusion was checked and monitored. CONCLUSION According to the fractographic analysis, occlusal interference was related to ceramic chipping in the incisal edge. Intraoral repair technique with composite resin was indicated for this moderate chipping. CLINICAL SIGNIFICANCE Retrieval analysis of chipping ceramic delivers better understanding of the failure origin and could prevent future failures. Intraoral repair is a practical and conservative technique and may be performed in a single clinical session without requiring the removal of prosthesis.

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Chipping of Veneering Ceramic in Lithium Disilicate Anterior Single Crown: Description of Repair Method and a Fractographic Failure Analysis

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Short Title: Chipping analysis of the veneering ceramic

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Purpose: This article presents a retrospective analysis of an anterior single crown that showed chipping in veneering ceramic, clinical stages of intraoral repair made in composite resin and fractographic analysis of the cause of the failure. **Materials and Methods:** A male patient experienced a chipping in an anterior ceramic crown made with a lithium disilicate infrastructure, which was installed in the element 22. The ceramic chipping occurred in the incisal and labial surface of the crown, one year after the installation. The presence of occlusal interference was observed in the clinical examination, which is probably responsible for chipping. Vinyl-polysiloxane impression was take from the patient and epoxy replica were produced from this impression. The replica was gold coated and inspected under the optical microscopy and scanning electron microscope (SEM) for descriptive fractography. After, the fractured area was repaired intraorally with composite resin and the patient's occlusion was checked. **Results:** Optical microscopy and SEM images shows that chipping initiated at the incisal edge, where it is possible to note an area of damage accumulation. At the labial surface, multiple arrest lines with their convex sides facing the incisal edge are presents. **Conclusion:** According fractography analysis, occlusal interference was related to ceramic chipping in the incisal edge. Intra-oral repair technique with composite resin is been indicated for this moderate chipping.

Clinical Significance: Retrieval analysis of chipping ceramic delivers better understanding of the failure origin and could prevent future failures. Intra-oral repair is a practical and conservative technique and may be performed in a single clinical session without requiring the removal of prosthesis.

Key words: Ceramic; Chipping; Failure; Fractography; Fracture; Intra-oral repair.

INTRODUCTION

Feldspathic porcelains have been largely used as veneering materials over frameworks constructed with both lithium disilicate glass-ceramics or zirconia. Although this type of restorative treatment shows high survival rates,[1] the literature reports failure rates around 15%, especially when zirconia infrastructures are employed.[2,3]

Feldspathic porcelains have relatively low fracture toughness, which explains, in part, high relatively high incidence of fractures of the veneering layer when all-ceramic prostheses are subjected to stresses.[4] Several causes have been associated with fracture and chipping of veneering ceramics, such as inadequate design of the infrastructure, irregular preparation, mismatch between the thermal expansion coefficient of veneering ceramic and infrastructure, inadequate laboratory procedures; porosity areas and surface defects after laboratory processing, inappropriate occlusal adjustment, trauma, parafunctional habits, presence of caries and periodontal disease.[5,6,7]

Fracture of the veneering ceramic is a clinical complication that should be carefully evaluated with regards to its cause, the possibility of repair or need of replacement.[6] In 2010, Heintze and Rousson introduced three chipping grades and suggested different clinical approaches for each one of them: grade 1 (small venner chipping, no further treatment needed, except polishing); grade 2 (moderate venner chipping, intra-oral repair performed with resin composite) and grade 3 (severe chipping, needing replacement of the PDF).[1] Chipping fractures occurring at the incisal edge of incisors may be considered as moderate and usually occur due to occlusal problems, such as premature contacts and interferences.[6,8]

Fractography has been used as an important tool to identify the cause of fracture, and at the same time describe the observed failure mechanism.[9] By means of fractographic analysis, one can identify the fracture origin, the direction of crack propagation and how it interacted with the material microstructure.[8] For ceramic materials, various fractographic features have helped understanding and preventing failures of dental prostheses.[9]

Whenever possible, fractured areas should be repaired as in most cases they represent an aesthetical and functional problem for the patient.[5,7,10] Intra-oral repair is a minimally invasive clinical approach that involves the direct restoration of the fractured area, without involving multiple clinical sessions and/or laboratory costs.[6,11] Usually, repairs are made with restorative resin composites, however, before repairing a fractured area, it is essential to check whether the prosthesis has satisfactory marginal fit and proper aesthetics.[10] Furthermore, the type and size of the fracture must be taken into consideration because the clinical management and adhesion protocols are directly influenced by these factors and it has been shown that smaller areas that do not affect oral function are more easily repaired by clinicians.[11]

In order to guarantee the longevity of intra-oral repair, a strong and stable adhesion between the restorative material and the fractured restoration must be obtained.[12,13] A number of techniques have been suggested to make intra-oral repairs with the objective of achieving good bond strength to the various substrates that may be present at the broken restoration.[6,13] Some authors have suggested that fracture surfaces containing metal or polycrystalline ceramics should be treated by sandblasting with alumina particles (with or without silica-coating), whereas surfaces containing feldsphatic porcelains or glass-ceramics should be etched with 10% hydrofluoric acid for 2 min and 1 min, respectively.[12,14] After application of surface conditioning methods, adhesion promoters (e.g., silane) and resin composite materials should be applied according to manufacturers' instructions.

The aim of this case report was to describe a clinical case where chipping of the veneering feldspathic porcelain was analyzed using fractography to assess the possible causes of failure and repaired with composite resin.

MATERIALS AND METHODS

Case report

A 60 years old male patient was rehabilitated in April 2014 with anterior all-ceramic crowns constituted with a lithium disilicate based glass-ceramic framework veneered with feldspathic porcelain. After one year, in a follow-up session, a failure by chipping of the veneering ceramic was observed at the incisal edge and involving a small part of the labial surface of the tooth 22. In the clinical exam, an occlusal interference was found in the incisal edge of the refereed tooth, which probably led to chipping of the feldspathic porcelain (Figures 1a-c). The fracture was relatively small, had elliptical shape, its linear size from the incisal edge to the end of the fracture was 2mm. Due to the small size of the fractured area (chipping grade 2),[1] an intra-oral repair with resin composite was indicated.

In order to identify the cause of failure, an impression of the fractured area was made with a vinyl-polysiloxane (Express XT, 3M ESPE, St. Paul, MN, USA) before making the intra-oral repair. A replica in epoxy resin was made from the silicon impression to enable the fractographic analysis. The replica was gold-sputtered and observed under both optical and scanning electron microscopes at different magnifications.

Since the fracture of the restoration did not expose the lithium disilicate infrastructure, the classic technique for adhesion to feldspathic porcelains was used. This is a predictable technique because it uses hydrofluoric acid (HF) associated to posterior silane application in order to obtain good bond strength between the porcelain and composite resin.[14] The clinical procedure was performed with absolute isolation to protect the soft tissue from the hazardous effects of the hydrofluoric acid and to avoid saliva contamination during the adhesive procedure.[14]

Initially, the restoration shade was selected with the help of a color guide (Linearguide 3D Master, VITA Zahnfabrik, Bad Säckingen, Alemanha). After cleaning the fractured area with fluorine-free paste and properly isolating it, the glaze around the fractured ceramic area was removed with a fine-grained diamond bur, creating a slight bevel. This approach homogenized the surface roughness and allowed for a smoother transition between the resin composite and the porcelain.[6] The adjacent prosthesis was protected with a polyfluorethylene tape and the remaining porcelain material in tooth 22 was protected with glycerin gel. Sandblasting was performed for 10 seconds, with silica particle size range of the 50µm, blasting pressure at 2.5 bar and at a distance of 10 mm in circling motion, rotating the nozzle (Microetcher, Danville Engineering, Danville, CA, USA).

After air-abrasion, the bonding area was washed, cleaned with 70% alcohol and conditioned with 10% hydrofluoric acid (Porcelain Etch, Dentisply, York, PA, USA) for 2 minutes. The area was then thoroughly washed again and dried. A silane coupling agent (Ceramic Primer, 3M ESPE, St. Paul, MN, USA) was applied for 3 minutes and dried with oil-free air. Silane application is recommended to create covalent bonds between the surface of the feldsphatic porcelain and the bonding agent[13]. A bonding agent

(Optibond FL, Kerr Corporation, Orange, CA, USA) was then applied to the ceramic surface and photo cured for 20 seconds. The intra-oral resin composite repair (Estelite Sigma Quick, Tokuyama Dental Corporation, Tokyo, Japan) was constructed using the incremental technique. Finishing and polishing procedures were done with rubber tips (Flexi Cups, Cosmedent, Chigaco, IL, USA; Soft-Lex Spiral Finishing, 3M-ESPE, St. Paul, MN, USA) and polishing paste (Porcelize, Cosmedent, Chicago, IL, USA).

After removal of the rubber dam, the occlusion was checked with carbon tapes and the adjusted area was repolished with rubber tips. This step is critical to minimize the recurrence of the failure due to occlusal overloading.[7,10,13] The sequence of clinical procedures is shown in Figures 2a-l. The patient authorized data collection the use of his clinical images by means of signing the Informed Consent Term. All data regarding the restorative steps were retrieved and analyzed.

Fractographic analysis

The epoxy replica was cleaned in an ultrasonic bath (Elmasonic E, Analítica, São Paulo, São Paulo, Brazil) containing water for 20 minutes and dried. Next it was gold-sputtered (Emitech SC7620, Quorum Technologies Ltd, Laughton, UK) and taken to the stereomicroscope (Zeiss Discovery V20, Zeiss, Oberkochen, Germany) for initial fractographic analysis. Further mapping of the fracture surface was carried out under SEM at high vacuum (INSPECT S50, FEI, Brno, Czech Republic) operating at 15 kVb spot 5.0, working distance of 17 mm at varied magnifications in order to highlight the most important fractographic features.

RESULTS

Fractography analysis

The analysis of the fracture surface under stereomicroscope clearly shows that the fracture initiated at the incisal edge, where it is possible to note an area of damage accumulation (Figures 3ab) most likely due to the fact that the incisal edge of the lower incisor hit many times this area after multiple mastication cycles. The chip fracture was wider at the incisal edge and became narrower towards the cervical direction, resulting in a triangular shape (Figure 3a). Far from the incisal edge, at the labial side, it is possible to clearly note multiple arrest lines with their convex sides facing the incisal edge, which indicates that the direction of crack propagation was from incisal edge towards the cervical region. The palatal view (Figure 3c) shows the incisal area with damage accumulation, which was the origin of the fracture event.

The SEM analysis (Figures 4 and 5) corroborated the information obtained in the stereomicroscope. Figure 4a shows an overview of the chip; it is clear that the origin was at the incisal edge, where multiple damage accumulation areas can be noticed. Towards the cervical area, multiple arrest lines in the form of half ellipses are seen along with numerous hackles and wake hackles that propagated up to the end of the fracture event in the region where the chip became narrower. Figure 4b shows a palatal view of the tooth where it is possible to note the damage zone in the incisal edge where the fracture started.

Figure 5 shows the detailed mapping of the entire fracture event under SEM. In the center of this figure, it is possible to note the overview of the chipped area. The surrounding micrographs present higher magnifications of the areas of interest. In Figure 5a, it is possible to note the damage zone area delimited by concave cracks at the top. Figure 5b shows multiple arrest lines and many hackles and wake hackles indicating that the direction of crack propagation went from the incisal edge to the cervical area. Figures 5c and 5d also show arrest lines with hackles and wake hackles indicating that in this area the crack propagated from the incisal edge to the distal surface of the incisor.

DISCUSSION

The fracture of the veneering ceramic in bilayered prostheses can severely compromise the aesthetics and function of the restorations, affecting their longevity. In most clinical trials, the failure of porcelain/zirconia restorations was related to chipping of the veneering layer.[2,3] Where applicable, the intra-oral repairs made with resin composites is conservative minimally invasive approach with very good cost/benefit ratio.[4,5,6,7,11] This type of repair is associated to reduced cost for the patient; reduced treatment time and increased longevity of the restoration.[6]

Depending on the type and size of the fracture, different substrates may be exposed, requiring different treatment methods involving etching agents, adhesion promoters and/or sandblasting to ensure good adhesion of intra-oral repair to the ceramic surface.[6,13] These treatments can promote mechanical interlocking, chemical bonding, or both.[13] For feldsphatic ceramics, the most commonly used surface treatment is hydrofluoric acid etching (HF).[14] However, other treatments such as air-abrasion with aluminum oxide particles w (with or without a surrounding silica layer), silanization or a combination of both has also been employed.[4,6,10,13] Since feldspathic porcelains are rich in silica, hydrofluoric acid interacts with the microstructure of this material, creating a porous surface that aids in mechanical retention of the resin composite used in the intra-oral repair technique.[4] This approach favors the bonding procedure and increases the repair longevity.[10] However, hydrofluoric acid needs to be carefully used intra-orally due to possible damage to soft tissues and therefore the use of absolute isolation is essencial.[12,13,14]

In this case report, the decision to make an intra-oral repair was related to the reduced size of the fractured area and the microstructure of the exposed ceramic substrate. During the clinical examination an occlusal interference was detected in the restored tooth and identified as the cause of the fracture event.[8,9] The fractographic analysis indicated that the fracture of the porcelain layer initiated at the incisal edge where an area of multiple damage accumulation was present. This damaged area was probably created by the occlusal interference, and resulted from the constant attrition/impact of the lower incisor on the incisal edge of the upper lateral incisor. Each time the lower incisor hit the edge of the upper incisor, multiple small cracks propagated by the mechanism of slow crack growth that was enhanced in saliva. As a result, a damaged area was created and a larger crack propagated from the incisal causing the chip seen in Figures 3, 4 and 5. Unfortunately, as seen in many clinical cases, it is difficult to measure the size of the fracture origin, as it was related to a complex damaged area.

The fractographic features found in the fracture surface allowed for determination of the direction of crack propagation from the incisal edge towards the cervical/proximal areas. It is possible that, besides the excessive occlusal loading occurring at the incisal edge, residual tensile stresses resulting from cooling the crown from the sintering temperature of the veneering ceramic to room temperature may have helped with propagation of the main crack. However, the low fracture toughness and low resistance to slow crack growth of the veneering material associated with excessive masticatory stresses are likely to be the main factors responsible for this fracture.

CONCLUSIONS

Fractography analysis of the fracture in the veneering ceramic of lithium disilicate crown revealed that the failure was a consequence of crack formation during function, probably due to an occlusal interference. Intra-oral repair using resin composite could prolong aesthetics and function for failed veneering ceramic on all-ceramic crowns.

REFERENCES

1. Heintze SD, Rousson V. Survival of zirconia – and metal – supported fixed dental prostheses: a systematic review. Int J Prosthodont 2010;23:493-502.

2. Sailer I, Pjetursson BE, Zwahlen M, Hämmerle CH. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part II: Fixed dental prostheses. Clin Oral Implants Res 2008;19:326-328.

3. Koenig V, Vanheusden AJ, Le Goff SO, Mainjot AK. Clinical risk factors relates with zirconia-based restorations: an up to 9-year retrospective study. J Dent 2013;41:1164-1174.

4. Kimmich M, Stappert C. Intraoral treatment of veneering porcelain chipping of fixed dental restorations. J Am Dent Assoc 2013;144:31-44.

5. Özcan M, Neidermeier W. Clinical study on the reasons for and location of failures of metal-ceramic restorations and survival of repairs. Int J Prosthodont 2002;15:299-302.

6. Özcan M. Evaluation of alternative intra-oral repair techniques for fractured ceramic-fused-to-metal restorations. J Oral Rehabil 2003;30:194-203.

7. Hickel R, Brüshaver K, Ilie N. Repair of restorations – Criteria for decision making and clinical recommendations. Dent Mater 2013;29:28-50.

8. Du Q, Swain MV, Zhao K. Fractographic analysis of anterior bilayered ceramic crowns that failed by venner chipping. Quintessence Int 2014;45:369-376.

9. Pang Z, Chughtai A, Sailer I, Zhang Y. A fractographic study of clinically retrived zirconia-ceramic and metal-ceramic fixed dental prostheses. Dent Mater 2015;31:1198-1206.

10. Reston EG, Filho SC, Arossi G, Cogo RB, Rocha CS, Closs LQ. Repairing ceramic restorations: final solution or alternative procedure? Oper Dent 2008;33:461-466.

11. Loomans BAC, Özcan M. Intraoral repair of direct and indirect restorations: procedures and guidelines. Oper Dent 2016;41:(Epub).

12. Özcan M. How to repair ceramic chipping or fracture in metal-ceramic fixed dental prostheses intraorally: step-by-step procedures. J Adhes Dent 2014;16:5.

13. Elsaka SE. Repair bond strength of resin composite to a novel CAD/CAM hybrid ceramic using different repair systems. Dent Mater J 2015;34:161-167.

14. Özcan M, Volpato CAM. Surface conditioning protocol for the adhesion of resin-based materials to glassy matrix ceramics: how to condition and why? J Adhes Dent 2015;17:292-293.

Legends

Figures:

Figures 1a-c Photos of a) chipping of the veneering ceramic (22), b) side view of chipping, c) presence of the occlusal interference.

Figures 2a-l Photos of a) shade selection (22), b,c) removal of the glaze layer, d) protection of the prosthesis and veneering ceramic, e) hydrofluoric acid, f) silane coupling agent, g) curing of the adhesive resin, h) composite resin, i,j) finishing and polishing, k) intra-oral repair, l) follow-up after one year.

Figures 3a-c Photos of a) labial view of the crown (22), b) fragments of the horizontal fractured area, c) coronal fragments just above the metallic insert.

Figures 4a-c a) Overview labial view, b) incisal/palatal view at lower magnification and c) higher magnification.

Figure 5a-d SEM – Mapping of fracture surface.

Figures:

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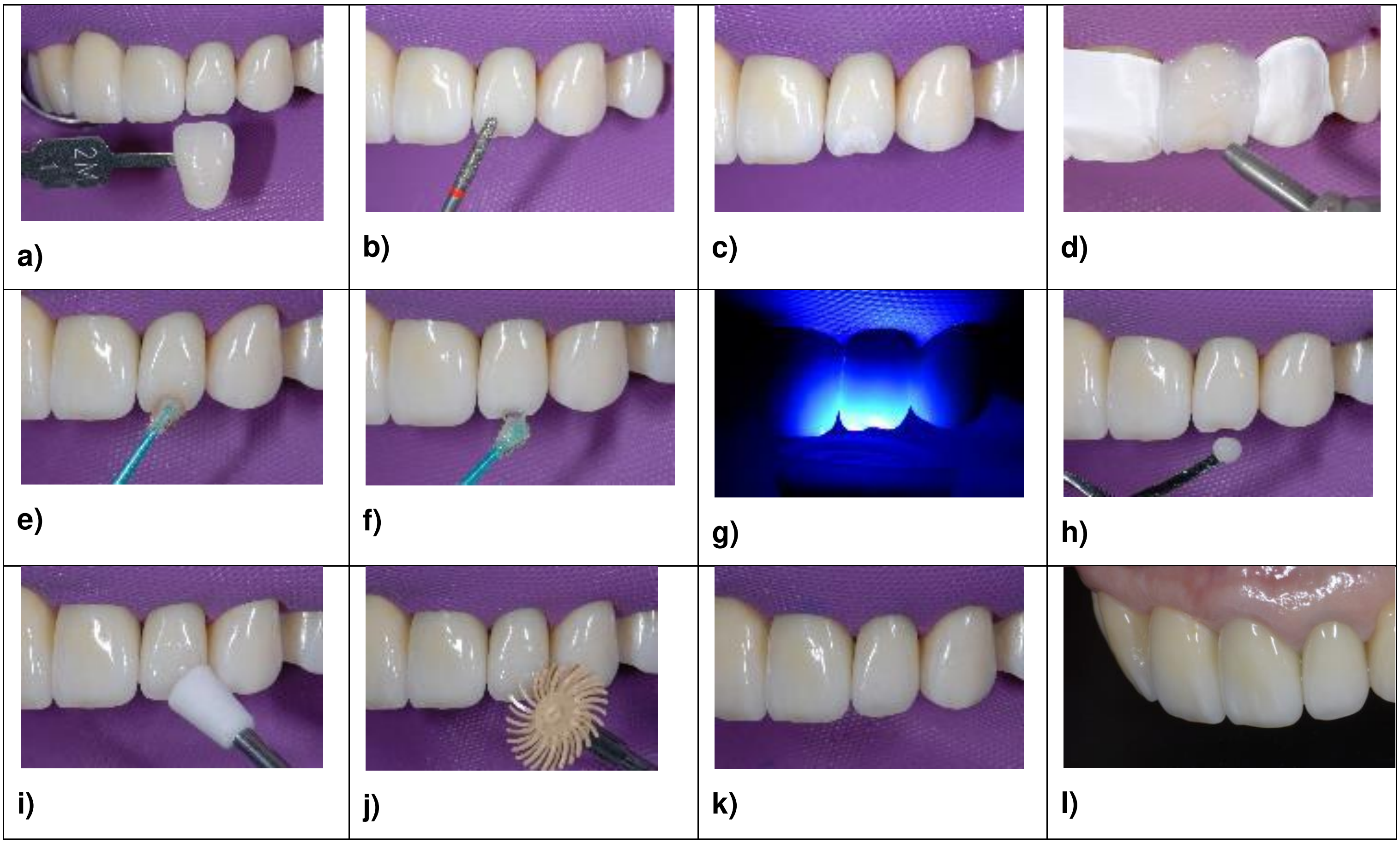

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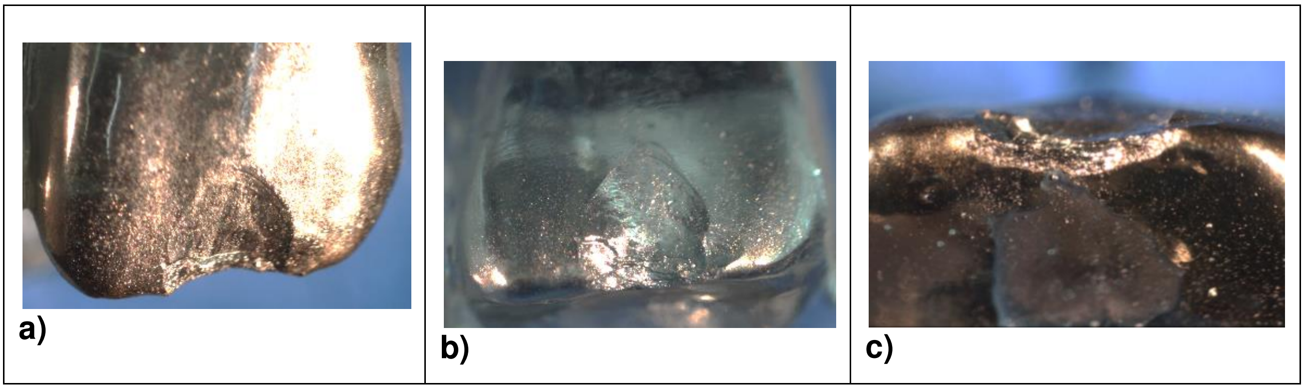

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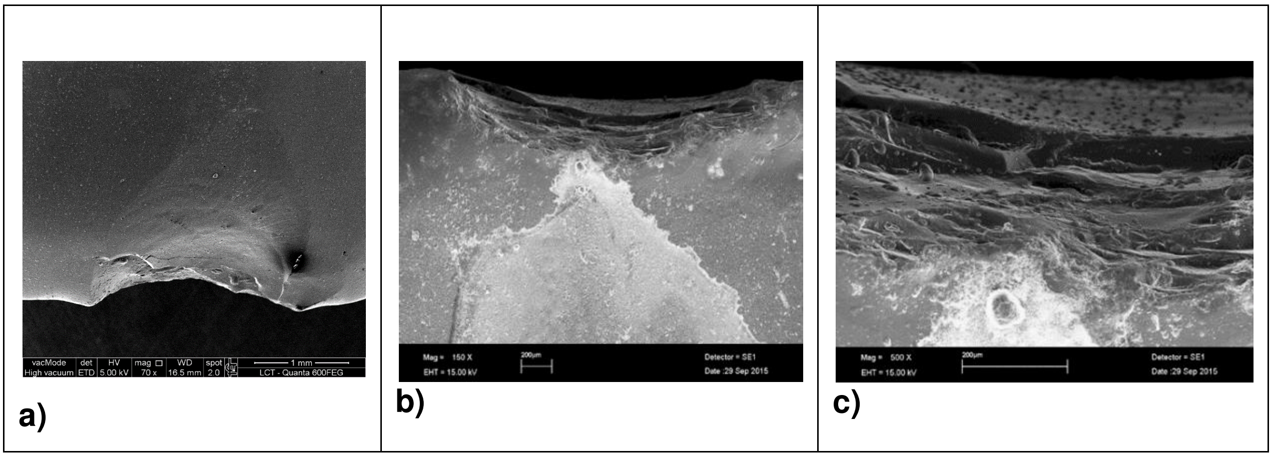

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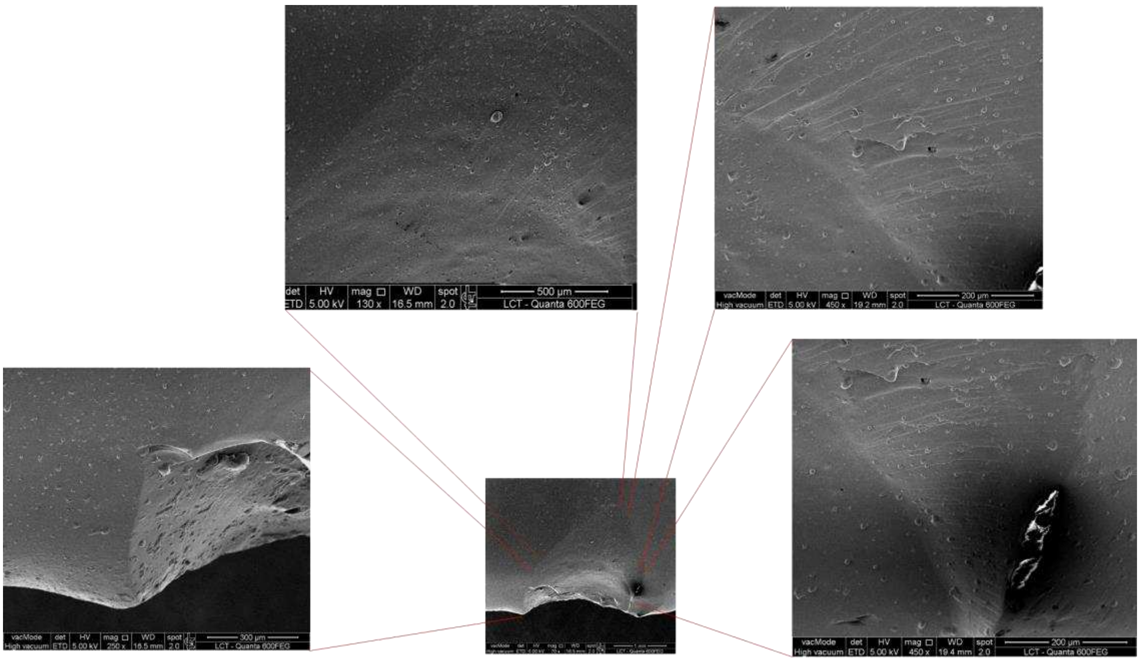

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